Multiple Telegraph

Electrical Experiments
by AGB

Vol. II

Hooper, Lewis & Co., Manufacturing Stationers, 122 State Street, Boston.

Tuesday April 18th 1876.

1. Experimented with lead pencils of different kinds to find out which was the best for the purposes of Autograph Telegraphy.

The following pencils were used: —

1. Steamboat No 2.
2. W. Cundy No 2
3. Eagle No 2
4. Faber No 2
5. Faber No 4
6. H. Ropes N. Y.
7. Graphite de Siberia de la Mine Alibert.
8. Pure plumbago.

Some words were written with each pencil upon a card. Some sulphate of copper was poured on the card & iron filings sprinkled in.

The iron would turn brown and the plumbago would be unaffected until the iron & plumbago were brought into contact by rubbing

The results seem to indicate that a soft lead pencil produces the best results, & that Faber's & Eagle's No 2. are the best pencils for the purpose

2. The iron filings became quite warm to the touch –

Thoughts.

The action does not seem to me to be a pure chemical action, for it seems necessary to have the iron <u>touch the plumbago</u> in order that there should be a deposit on the later.

Prof Horsford suggested that the iron & the plumbago really formed a battery – but I could not see how any action could take place until there was a circuit. I now think that this really <u>is</u> the action – & that a circuit is formed when a particle of iron <u>touches</u> a particle of plumbago.

If this is so it is probable that other metals may take the place of iron. Some metals should be selected very far away from plumbago in the electro- series of elements – Try zinc instead of iron. This would give the same elements that have been adopted in batteries – zinc & carbon

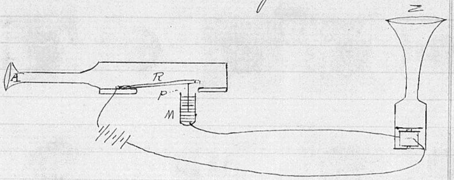
Noted April 19th. 1876 by A. G. B.

Copied Saturday April 22nd by M. G. H.

Wednesday April 19th 1876.

1. Mr. Watson assisted me in trying my new reed-arrangement today.

Figure 1.



Upon blowing into A, the reed R vibrated, causing the plumbago style, P, to dip into Mercury M. Sound loudly audible from Z.

2. Glycerine placed on top of mercury M did not seem to interfere with the effect at Z.

3. Glycerine was substituted for the mercury M, and the style P allowed just to dip into the glycerine. No sound audible from Z.

4. Style P allowed to dip deeply into the glycerine in M.

Sound audible from Z fully as loud as when mercury had been used in M.

5. Experiments to produce metallic coating on lead pencil marks.

All the marks were made heavily with a No. 2 Faber pencil.


Iron
No 2
Iron by Hyd.
No 3
Brass
No 4
Zinc
Zinc
No 6
Zinc
pressed in & washed off
Zinc
No 7
No 8
Zinc
No 9
Zinc
No 10
Zinc
No 11
Zinc
No 12
No 13
No 14
No 15
No 16
No 17
No 18
Moist. with Sulf. of Cop. + zinc filings sp. on.
No 19
No 20
No 21
No 22
No 23
No 24
AB
AGB
No 26

No 1. Card moistened with sulphate of copper & iron filings rubbed in slight deposition of copper.
No 2. Iron obtained by hydrogen substituted for the filings. No effect.
No. 3. Brass filings employed. No effect
No 4. Zinc filings employed. An immediate deposition of copper. The zinc became quite black. The copper deposited was soon covered with a black deposit, so that it lost the metallic lustre it had when first formed.
No 5. Zinc filings with same result
No 6. Zinc filings pressed close to card for a moment & then instantly washed off.
A distinct trace of metallic copper upon the plumbago.
No 7. Zinc filings were scattered upon the dry card they were then washed off with sulphate of copper.
An immediate deposite of copper took place
No 8. Zinc fillings sprinkled on the moistened card & lightly brushed with a paste brush.
Immediate deposite of copper.
No 9. Card moistened with sulphate of copper. Zinc filings sprinkled on

on card + pressed firmly with the fingers for about half a minute
Result – Copper + black deposit upon the plumbago

No 10 Moistened card. Zinc sprinkled on – rubbed with fingers and instantly washed off – Result – Metallic copper deposited

No 11. Same experiment as last.
Same result.

No 12. Moistened card held against a zinc plate for a moment.
Result uncertain

No 13. Experiment 12 repeated.
Distinct traces of copper deposited

No 14 Same as last.

No 15. Card moistened in sulphate of copper held for about a moment in close contact with zinc plate.
Traces of white deposit.
Looks like zinc – Worked a Morse Sounder through the white deposit.

No 16 Card moistened in dilute sulphuric acid – + held for one moment against a zinc plate
No deposit

No 17. Same experiment as No 16.

No 18 Card moistened with sulphate of copper and held closely against zinc plate for one minute.

Very slight trace of copper deposit not enough to work Morse Sounder through it

No 19. University paper. Sulphate of copper + zinc. Slight deposit formed.

No 20. The paper was moistened with sulphate of copper.

Zinc filings were added, + immediately washed off.

A slight metallic deposit was left on the plumbago

More sulphate of copper was poured on the paper + iron filings rubbed on.

Best result obtained yet. Good metallic deposit. Sounder works well through it.

No 21. Same experiment as last

No 22. Same experiment with card instead of paper.

Not quite so good deposit.

No 23. Same as experiment 20. Result very good indeed

No 24. Same as No 20 excepting that the iron filings were allowed to lie on paper, + were not rubbed on.

Best result yet. Good metallic deposit.

No 25. Same as last. Same result.

No. 26 paper immersed in Sulphate of copper & zinc filings sprinkled in and allowed to float on ~~surface~~. Copper deposit formed upon plumbago.

Best & thickest deposit yet obtained

Noted April 19th 1876 by A.G.B.

Copied April 22 1876 by M.G.H.

Saturday April 22d 1876

1. Upon repeating the experiment of vibrating plumbago in mercury (Page 3 Exp. 4) it was found that the plumbago struck a copper wire immersed in the glycerine so that an intermittent current had been created. When the plumbago was caused to vibrate freely in the glycerine no sound was audible from Z (Fig 1 page 3) however deeply the plumbago was immersed.

2. When the plumbago was vibrated in Sulphate of copper a slight sound proceeded from Z (Fig 1 Page 3).

3. Continuation of experiments to produce metallic coating upon lead pencil marks.

No 1. In this and all the other experiments made today, the zinc filings were immersed in water before being sprinkled upon the paper so that they should at once sink when placed in Sulphate of copper.

In No 1 the paper was first immersed in water then the writing was thickly covered with moistened zinc filings. Another

piece of paper was placed over the filings to keep them in place and the whole was placed in Sulphate of Copper.

No 2. Same as last excepting that the second piece of paper to keep the filings in place was omitted.

No 3. Same as No 1 save that the filings were thinly scattered on the paper.

No 4. Same as last excepting in the omission of the paper covering over the filings.

No 5. Same as No 1 save that the vessel containing the sulphate of copper was violently shaken so that the zinc filings could not rest long on one spot.

No 6. Same as last without paper covering for the filings

No 7. Same as No 2 excepting that the filings were allowed to be in contact with the plumbago all night. Noted by A. G. B. April 28th 1876

Sunday April 23d 1876

1. Experiments to produce metallic deposit upon lead pencil marks upon paper. The paper was placed in sulphate of copper and mercury poured over the writing. No deposit.

2. Zinc filings were dissolved in mercury forming a pasty amalgam which was placed upon the writing and then sulphate of copper poured on.

A deposit, like mercury, made its appearance on the plumbago. Or rather the amalgam adhered to the plumbago surface. No 1 and No 2 are specimens of the results obtained.

Noted April 23d 1876
by A.G.B.

Tuesday April 25th 1876

1	2	3	4	5	6	7
1	2	3	4	5	6	7
1	2	3	4	5	6	7

8	9	10	11	12	13
8	9	10	11	12	13
8	9	10	11	12	13

autograph

metallic ink
Apr. 24th
1875

AGB

AGB

AGB

AGB

AGB

L. T. Stanley
from AGB
April 24th
1876

Eureka

Eur

Tried experiments to see if the paper made any difference in the quality of the deposit – Experimented thrice with each kind of paper, & find that that marked 4 is the best for the purpose.

A. G. B. April 26th 1876
M. G. H. April 29th 1876.

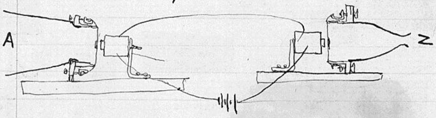
May 3d. & May 10th.

Exhibited instruments & their operation at Prof. Trowbridge's room Harvard University Tuesday May 3d 1876 & at the Academy of Arts & Sciences May 10th. 1876.

May 5th. 1876

Instruments at Mr. Hubbard's House. Experiment with the Telephone arranged as in Fig I.

Fig I



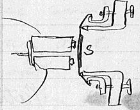
Mr. Hubbard and Miss Hubbard spoke simultaneously into A. I was able to hear both voices at Z. Articulation unintelligible. Large aperture vowels such as ɩɩ ʃ] and diphthongs ʃɩ ʃ7]ɩ]7 are heard distinctly at Z. Other vowels are also audible

and occasionally certain consonants. With a powerful battery I have heard a few sentences perfectly. For instance "What hath God wrought" was on two or three occasions perfectly distinct even to the th in "hath".

Noted by A. G. B.
May 19th 1876

May 22nd 1876

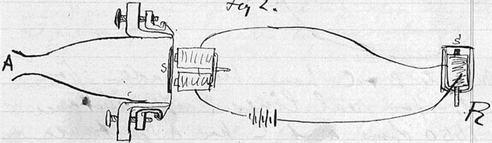
Fig I



1. Tried the effect of a double-pole magnet with the telephone this afternoon (as in Fig 1). Used as a Receiver with the telephonic organ — good results were obtained. Very loud sounds were emitted from S.

2. Telephone in Fig I was used as a Transmitter for the human voice. It was arranged upon circuit with the old Receiver R (Fig 2).

Fig 2.



Upon placing my ear against S' I could hear very distinctly the sounds that were uttered into A. Consonants + vowels were equally intelligible. Although my ear was pressed tightly against S' I heard the sentence "Mr. Bell ~~are~~ you going to the Centennial" with the utmost ~~dis~~ distinctness.

3. The effect was much better when Eddie Wilson spoke on the

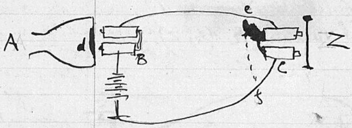
other side of the membrane so that the impulses of the voice tended to push it from not towards the magnet.

4. The telephonic organ was connected in circuit with the Receiver R (Fig 2) and the bridge of a violin was rested upon the spring S' (Fig 2). The resulting sounds could have been heard all over a large hall.

Noted by AGB
May 22nd 1876

June 30th 1876
Returned from Philadelphia Exhibition Monday.

Thus



Two Magnets B & C have been made for experiments upon real lines. The resistance of B is 1650 ohms [illegible] C has a resistance of 1600 ohms. A is ordin[illegible] telephone, the membrane has a small piece of [illegible] very thin sheet iron ("T[illegible]s iron") attached [illegible] it. ~~[illegible]~~ Z is a flat disk of Tagger's iron.

I tried the instruments this morning with four carbon cells I could not obtain any indications of attraction. Upon ~~[illegible]~~ placing my ear at Z however I could hear a click when the circuit was broken.

When Wilson sang into A I could hear the sounds of the voice at Z. Upon breaking the circuit at C the sounds were inaudible at Z. ~~[illegible]~~ No sounds were heard at Z when a wire connected e and f.

The sounds of Eddie Wilson's voice were reproduced by Z when there was only one cell on the circuit. This is most extraordinary especially when we consider ~~[illegible]~~ the resistance of the magnets alone ~~[illegible]~~ is equivalent to 3250 ohms or 320 miles of well-insulated telegraph-wire!

It is probable that ~~the~~ sounds proceed from Z when no battery is on the circuit — and that the inductive power of d acting upon the residual magnetism of B creates an undulatory current in C. I fancied I could hear faint sounds from Z when no battery was on the circuit — but other noises were loud and besides I could ~~[illegible]~~ hear Eddie's voice through the air ~~[illegible]~~ although very faintly.

Over

2. When Eddie Wilson sang to Z faint sounds were audible from A. Four cells on circuit.

Thoughts.

Fig 2

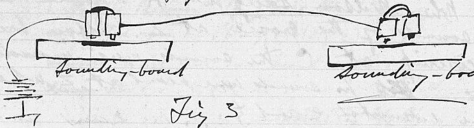
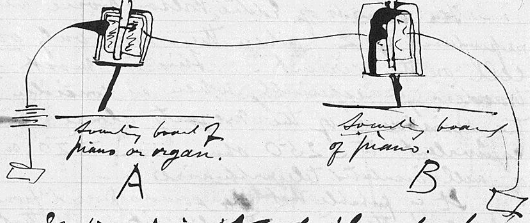


Fig 3



If piano A is ~~[illegible]~~ played why should not piano B copy every note since the sounding board is set in vibration.

And if so what need of other apparatus for Multiple Telegraphy. Play any note of one piano & the signals will come on the string of the other piano. The sounds will thus be sifted <u>after</u> they leave the wire.

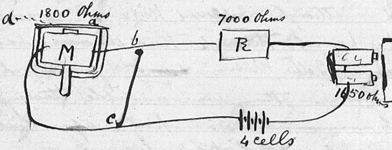
July 3d 1876.

1. Williams made magnet for me like that shown in Fig 1.
The resistance of the coil is 1800 ohms.

Fig 1.

2. The instrument shown in Fig 1 was connected upon circuit with a telephone as in Fig 2, and resistance inserted as at R Fig 2.

Fig 2.



Four cells of a carbon & bichromate battery were employed. As the total resistance of the circuit was equivalent to 10,450 ohms the battery had an inappreciable effect upon the magnetism of M. The steel-spring armature a, ~~did not~~ was not sensibly attracted by M. And yet sounds uttered into T were heard ~~at~~ proceeding softly from a of M. The sounds were inaudible from a when a piece of copper-wire was laid from b to c.

Noted by A.G.B.
July 3d 1876

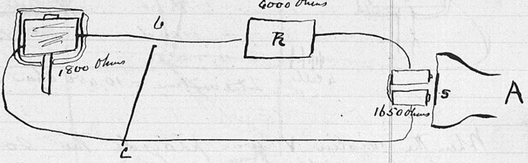
Thursday July 6th 1876

1. Instruments arranged as in Fig 2 page 17. Battery power gradually reduced to one cell. The sound emitted by a of M was little inferior in loudness to that heard when four cells were employed. It seems extraordinary that the vibration of a little piece of iron weighing a few grains should cause an audible sound upon a circuit of 10,450 Ohms resistance with only one cell of battery. There can be no doubt that the sounds are electrically produced although Edward Wilson's voice could be heard through the air also; for when Edw. Wilson ~~sang~~ prolonged his sounds — they were audible through the air b —————. But upon listening at a the sound was broken up so .... when the ~~cl~~ of magnet M was cut off from the circuit by tapping with the wire bc upon the point b.

2. The battery was entirely removed from the circuit and the Rheostat (R Fig 2 page 17) disconnected.
When E. Wilson sang into T the sounds were audible from a of M.

3. The Rheostat (R) was re-introduced into the circuit as in Fig I (page 19) and the resistance

Fig I

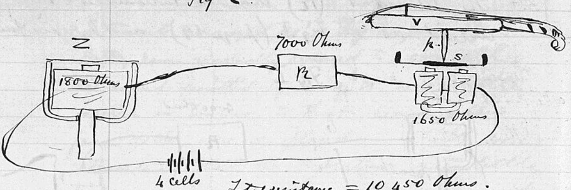


of the circuit was gradually increased. 4000 Ohms resistance was introduced and still the sounds that were ~~and~~ uttered into A were heard faintly proceeding from Z. The sounds were electrically produced as proved by the effect of the cut-off bc. When more than 4000 Ohms resistance was introduced the sounds audible at Z through the air were so much louder than those produced electrically at Z that it was difficult ~~of the~~ to determine whether the sounds heard at Z were due to electrical undulations or to the air.

4. A lead-pencil p (Fig 2 page 20) was placed against the spring S, of the telephone T and a violin V, was rested against p.

Arrangement upon circuit as in the diagram

Fig 2.



Total resistance = 10,450 Ohms.

When the violin V was played the sounds were clearly audible from Z.

Noted by AGB
July [illegible] 1876

Friday July [illegible] 1876

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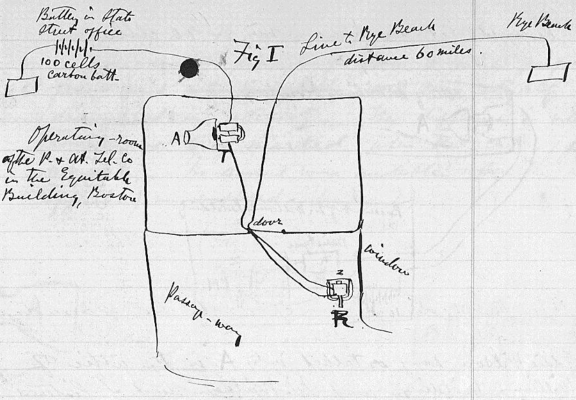
1. Had an opportunity of trying instruments upon a real line at the office of the Pacific & Atlantic Telegraph Company this morning at half-past six.

The instruments were arranged upon circuit as in Fig I page 21. Mabel spoke at A and I heard her voice at Z. This is the first time the human voice ~~has~~ been transmitted along a real telegraph wire. Mabel articulated the word "Alec—Alec". I heard her voice proceeding from Z but could not distinguish the articulation.

E. Wilson then sang and spoke into A. His



voice was plainly audible at z. I distinguished clearly the sentences "Do you understand what I say?" "Do you hear me" and a few other sentences.

2. The telephonic organ was connected in circuit in place of the Telephone T, &

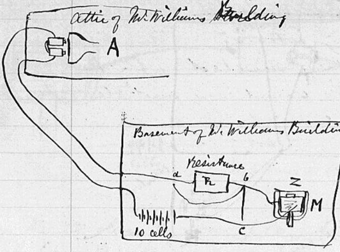
Every note & chord was loudly audible from the Receiver R.

The only defect in the experiment is that R is not placed entirely out of ear-shot of T — I am to experiment again on Sunday morning.

3. I took the telephonic Transmitter & Receiver for the human voice to Williams' this evening to try how much resistance I could transmit sounds through with the battery-power

he could let me have viz — 10 cells

Fig 2



Eddie Wilson sang ~~or~~ talked into A in the attic of Mr Williams building, and Mr Watson and I listened at Z Fig 2. Z was entirely out of ear-shot of A. A rheostat was ~~introduced~~ placed at R and the ~~amount of~~ full resistance 8105 ohms introduced into the circuit. The sounds proceeding from Z were perfectly plain and the articulation as distinct as upon a short circuit — but slightly fainter.

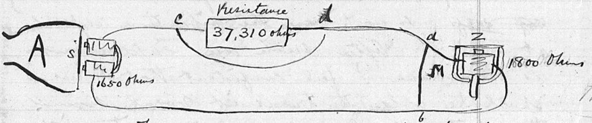
4. A second rheostat similar to the first was introduced at R ~~ohs~~ so that the total resistance at R was 16210 Ohms. The sounds at Z were not sensibly diminished in intensity. No sound was audible from M when the armature Z was removed.

5. A third rheostat (the largest in the store — containing a total resistance of 21,100 Ohms) was introduced into the circuit, so that the total resistance

interposed at R was 37,310 Ohms.

The sounds proceeding from Z were perfectly plain and ~~not perceptible~~ were very slightly diminished in intensity. The difference in intensity however was very marked when the cut off (ab) was used. No sound was audible when the cut-off (bc) was employed. (See Fig 2)

(Fig 3.)



Total resistance of circuit equals 40,760 Ohms.

6. No further resistance being obtainable it was decided to reduce the battery power.

The battery was reduced from 10 cells to 1 cell and still sounds were audible from Z (Fig 2) - very slightly fainter than when 10 cells were employed.

7. Upon removing the battery altogether as in Fig 3 - sounds were still perfectly audible from Z.

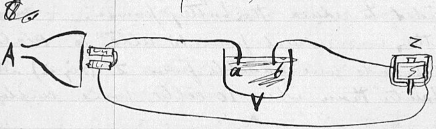
No sounds were audible from M when

(a) The armature Z was removed;
(b) When the circuit was broken;
(c) or when the cut-off (ab) was employed.

The sounds were much louder when the cut-off (cd) was used so as to cut out the resistance.

All these facts convinced me + Mr. Watson that the sounds audible at Z were electrically produced, and were not merely mechanically conducted along the wire. And yet it seems almost too marvellous for belief that the vibration of ~~the~~ a little piece of thin irons weighing only a few grains should induce electrical undulations upon a circuit ~~offering a lots~~ of 40,760 Ohms resistance (a greater resistance than from here to England) ~~off~~ ~~off~~ so as to have the vibration reproduced at Z. After such an experiment as the above I feel confident that we shall be able to transmit vocal sounds through the cable — and this too without a battery!

(Fig 4)

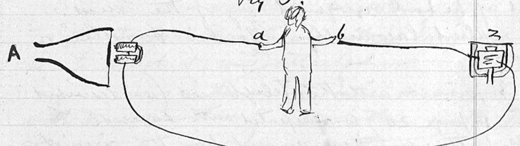


8. In order to be perfectly sure that a considerable resistance had been introduced into the circuit it was determined to introduce water into the circuit in place of the rheostats. The arrangement is shown in Fig 4. The sounds uttered into A were clearly audible from Z when the wires a and b just touched the water in the vessel, V. No sound was audible from

Z when either of the wires a ~~b~~ b ~~was~~ was removed from the water. The sounds audible at Z became suddenly louder when the wires a and b were allowed to touch one another.

9. The vessel of water, V (Fig 4) was next removed and the circuit completed by means of the human body. Mr. Watson took the wire, a (Fig 5) in one hand while I listened at Z. Nothing was audible at Z so long as the circuit was incomplete but the moment Mr. Watson completed the circuit by touching the wire, b, I heard (at Z) the sounds that were uttered into A by E. Wilson.

Fig 5.



No sensation whatever was experienced by Mr. Watson. While the ~~circuit~~ induced currents were thus passing through Mr. Watson's body I distinctly heard the following sentence proceed from Z. "Can you hear anything or nothing?"

Noted by A. G. B.

July ~~10th~~ 9th, 1876

Sunday July ~~10th~~ 9th 1876

1. I met Mr Downs at the Pacific & Atlantic Telegraph Company's Office in the Equitable Building about six o'clock this morning.

The telephonic organ was connected with the main line ~~at~~ to New York — and the New York operator was signalled to place his ear to his relay and let us know whether he heard anything.

I then played "Yankee Doodle" and "Auld Lang Syne" and a few chords upon the organ. Presently came a message from the New York operator that he had heard the music "~~[illegible]~~ elegantly". He was then asked if he had recognized any of the airs. He replied laconically "Yankee Doodle".

2. The experiment with the telephones (as described in par. 1 page 20) was repeated with success.

The battery was then removed from the circuit. It was unfortunate that the instruments T & R as shown in Fig I (page 21) were not out of ear-shot of one another so that I cannot say decidedly that the sounds uttered into A (Fig 1 page 21) were audible at Z — but I think & believe that they were. The experiment is to be repeated on Wednesday night at half-past ten when the instruments will be placed entirely out of earshot of one another. Noted by AGB July ~~10th~~ 9th 1876

Tuesday July 11th 1876

Tried improved apparatus at Williams' today with great success. Tried varying the shape of the ~~spring attached~~ armature attached to the membrane.

Fig 1

This 

 This

S is the ~~spring~~ armature with which I have hitherto experimented. It was attached to the membrane m. S' is the new armature consisting of a disk of thin tagger's iron ~~f~~ almost as large as the membrane m' to which it was attached.

Two instruments were arranged one with the armature S the other with the armature S' and the audible effects compared.

They were alternately arranged upon circuit with the Receiver M as shown in Fig 2 (page 22). The Transmitters were in the attic of Mr Williams' building and the Receiver M in the basement. Ten cells of a Carbon battery were employed and artificial resistance R to the amount of 16,210 ohms introduced into the circuit. When the instrument having the armature S' (Fig 1 page 27) was used the sounds proceeding from Z (Fig 2 page 22) were in-

-mensely louder than when the instrument with the armature S was employed.

2. When the armature S' was used conversation in an ordinary tone of voice was perfectly audible at the Receiving Instrument.

Indeed the softer the initial articulation the ~~more~~ distinct was the utterance at the other end of the line.

When the initial utterance was loud the final articulation was also loud but indistinct — and when the voice at the transmitting end was raised scarcely above a whisper the sounds at the receiving end were very faint but were perfectly distinct.

The total resistance of circuit was 19660 ohms.

Noted by A. G. B.

July 12th 1876

Wednesday morning July 12th 1876
(Thoughts)

1. Try the effect (a) of varying the size of the armature attached to the membrane.

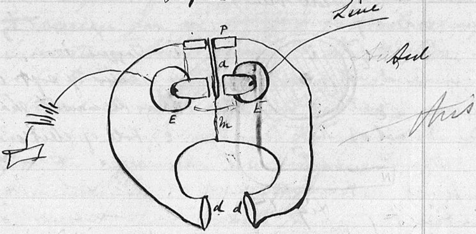
(b) Vary the mass — use thick pieces of iron attached to a sounding board.

(c) Use small electro-magnets as the armatures ~~&~~ attached to sounding board.

(d) Vibrate the electro-magnet instead of the armature.

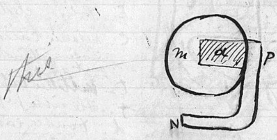
(e) Have arrangement similar to Siemens' polarized relay — see Fig I

Fig I



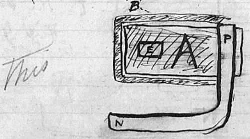
P. Permanent magnet. a armature attached to membrane m.
EE Electro-magnet. d,d, double ear-trumpets.

Fig 2
(side view of armature and membrane)



PN Permanent magnet.
m Membrane.
a armature.

Fig 3.
(side view of proposed armature without membrane)

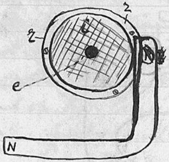


PN Permanent magnet
A Armature arranged in a bed (B) similar to a free reed.
E - One of the poles of the electro-magnet employed.

Fig 4

Another form of polarized armature without any membrane.

(Side view)

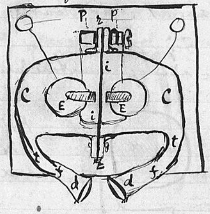


Thus

i. Taggers iron
z. rim of soft iron
PN, Permanent magnet
e, Pole of electro-magnet.

Fig 5

(Plan of instrument shown in Fig 4)

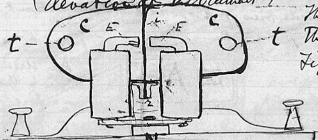


Thus

PP Pole of permanent magnet.
z. soft iron rim
i. Taggers iron
E. Poles of electro-magnet.
C. Metallic casing enclosing the whole instrument.
t. Metallic tube.
f. Flexible piping
d. Double ear trumpets

Fig 6

(Elevation of instrument)



Thus

The lettering is the same in Figs 4, 5, 6.

Noted G. A. M. July 12th/76

Wednesday evening July 12th 1876

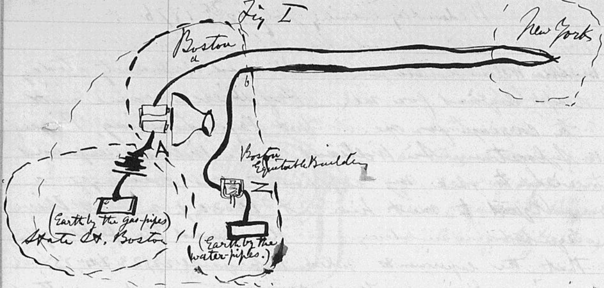
1 ~~Sir~~ Sir William Thomson was at Harvard University today and enquired for me. Prof. Pierce came with a carriage for me. Met Profs. Lovering, Pierce, Sylvester & Sir William. Sir William expressed wish to see my experiments this evening.

Agreed to meet him at 10.30 p.m. at the Equitable Building. He expressed the feeling that the experiments noted in pages 21, 22, 23, 24, 25, were inconclusive. — That there was no proof that the current had passed through the high resistance — ~~for~~ it might have taken the part of the earth in a real line and ~~the~~ a current have been formed only on the short part of the circuit (see Fig 2 page 20).

In Fig I page 21 — since the Receiving Instrument was not at Rye Beach, there was no proof that ~~the~~ a current was formed on the line — as the line itself might have taken the part of the Earth. He stated that the only way to be certain was to have the Transmitter and Receiver at the two ends of the circuit, although ~~it might~~ satisfactory results might be obtained by arranging the instruments as in Fig I (page 32.)

Over

Fig I



1. The lines of the Pacific & Atlantic Tel. Co. — were injured by the storm last night so that only four wires were in operation between N. Y. & Boston.

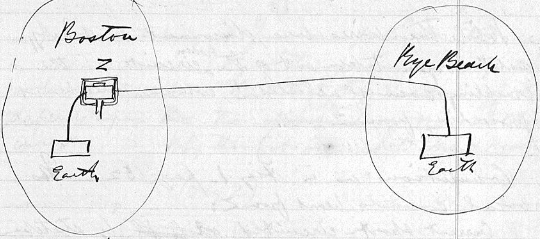
Two wires were crossed at N. Y. and the circuit completed ~~at~~ as in the diagram. The battery and gas-pipe earth were in State St. - Boston, and the instruments and water-pipe earth in the Equitable Building.

Upon listening at Z a strange crackling noise was heard, but no trace of vocal sounds. Sir William thought this was due to operating on adjoining lines, ~~or~~ to lightning, or to leakage to the earth at intermediate points. The effect was quite new to him and to me

2. ~~Rear~~ The instrument Z was arranged upon the line to Rye Beach without any battery on the circuit as in Fig 2 (page 33) and still these strange sounds were perceived. There was no other wire on the same posts with this wire, ~~ccc~~. Another line came to Boston from Rye Beach by a different route. The

two wires made the same earth at Rye Beach — and the other wire was being used at the time for some cable despatches. The sounds however were not suggestive of dots & dashes at all — and an operator who listened was quite unable to read any signals. The sounds ~~were of a~~ consisted of an irregular succession of explosive noises similar to those heard from the core of an electro-magnet when the circuit upon which it is placed is broken.

Fig 2.



3. The telephonic organ was substituted for the telephone A (Fig I) The sounds were clearly audible from Z.

~~4. We telegraphed to N.Y. to have the wires disconnected and left free in the air — and still musical sounds proceeded from Z as before.~~

4. We telegraphed to New York to have the operator pass the current through his relay. He did so but could not perceive any sound.

5. We told him to disconnect his wires and leave them free in air. He did so, and still musical sounds proceeded from Z (Fig 1) This showed conclusively that there was some short-circuiting of the current – ~~[illegible]~~ leakage from one wire to the other by the posts, – ~~or [illegible]~~ probably.

6. While the wires were disconnected at N.Y. and the organ taken out of the broken circuit – the crackling sounds alluded to above were heard proceeding from Z.

7. Connections as in Fig 1. page 32 – No vocal sounds heard from Z.
Current short-circuited ~~[illegible]~~ by stretching a wire from a to b — vocal sounds were clearly audible from Z.

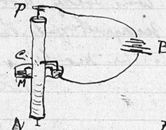
The Telephones (Transmitt. + Rec.) with which we have experimented have been presented to Sir William Thomson as I have duplicates.

Noted by AGB
July 17th 1876

Thursday July 13th. 1876

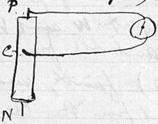
1. Tried an apparatus I had constructed a long time ago by Williams but which had produced no effect. It has long been known that when a current of electricity is passed through

(Fig I)



a permanent magnet from one pole P to the centre C, or vice-versa — that the permanent magnet (PCN) revolves upon its own axis and that the direction of the rotation depends upon, ~~the~~ the ~~direction~~ polarity of the voltaic current. Why then (it occurred to me many months

(Fig 2)



ago should not the converse be true. If a continuous current passed along the circuit PgC (Fig 2) causes rotation in PCN — why should not the rotation of PCN cause a continuous current upon the circuit PgC — and deflect a galvanometer needle (g). In former experiments the

magnet had been moved by hand, but to-day it was rotated by steam-power. "No deflection of the galvanometer was observed. The galvanometer was an upright one. ~~out~~ The needle was weighted at one end, and a permanent magnet was placed below in order to keep the needle in position.

The steel of which the magnet PCN was made was very poor and it was not well magnetized. "Have ordered another instrument to be made.

Noted by AGB
July 17th 1876

Friday July 14th 1876

1. Repeated experiments with telephones & high resistance making connections as in Fig. I page 37. Sounds audible from Z that were uttered into A.

2. Resistance was placed in the circuit by passing the current through plain water at W and W' (Fig 2) Sounds uttered into A audible from Z.

3. Sounds uttered into A (Fig 2) faintly audible from Z, when the battery was removed from the circuit.

Noted by AGB
July 17th 1876

Fig I

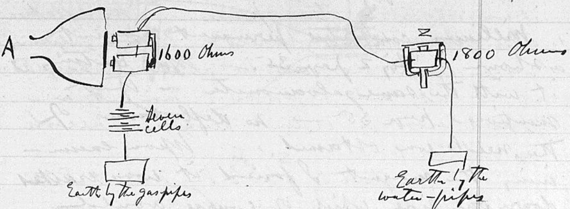
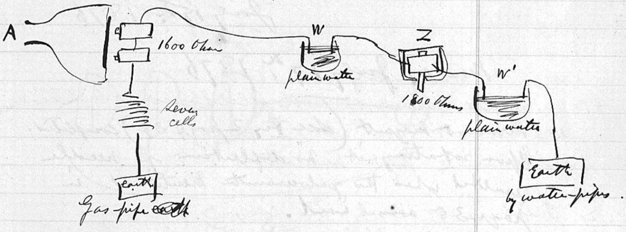


Fig 2



Noted by AGB
July 17th 1876

Saturday July 15th 1876

1. Williams completes permanent magnet as shown in Fig 2 page 35. — Upon testing it with the same galvanometer as that mentioned page 35 — no deflection of the needle was obtained. Upon examining the magnet I found it was cracked down one side which of course would prevent the circulation of currents.
Ordered another to be made.

Noted by AGB
July 17th 1876

Monday July 17th 1876

1. Permanent magnet (see Fig 2 page 35) completed. Upon rotating it no deflection of needle resulted when the galvanometer mentioned in page 35 was used.

2. Upon using a delicate astatic needle as in Fig I page 39 — a deflection of 75° ~~degrees~~ was at once obtained when PCN was rotated. The needle swung between 30° and 75° gradually coming almost to rest ~~about~~ at 55°.

3. Connections made as in Fig 2 page 39. Galvanometer needle (g) flew up to its stop at 90°

Fig I

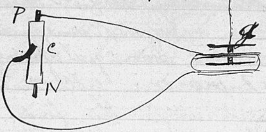


Fig 2

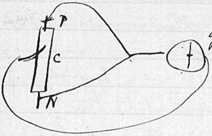


Fig 3

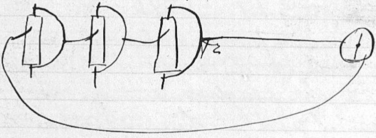


Fig 4

4. Figs 3 and 4 show batteries of permanent magnets. Fig 3 shows the arrangement for intensity and Fig 4 for quantity.

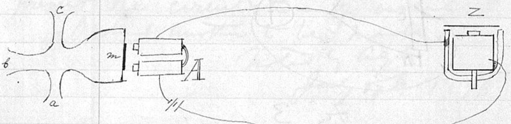
Noted by A. G. B.
July 17th 1876

Saturday Aug. 5th 1876

Brantford Ontario.

A wire was arranged from one of the outhouses to a table on the verandah. I attempted for the first time to send three voices simultaneously along the wire - and the experiment was a perfect success.

Fig I



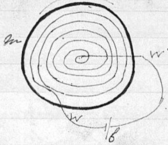
Three mouth pieces a. b. and c, were arranged so as to direct the voices of three persons upon the single membrane m. Mary Frances and I then sang the three parts of some of Bishops glees into the mouth pieces a b & c and the sounds were perfectly audible at Z. The experiment is a very important one for it shows that with the undulatory current ~~there must~~ a single transmitting instrument A will suffice for any number of simultaneous messages — while with the inter

mittent current there must be a distinct instrument for each message sent — and in addition there must be special instruments for inducing the current upon the line in order that communication may be established in both directions The more I think of it, the more I see that the undulatory current is the thing

But one thing more is wanted and that is to find a way of strengthening the sound at Z. I am thinking all the time of the improved apparatus & I am gradually working out the details in my mind. I am convinced now that the undulatory current will travel to any distance and that there will be no difficulty in working it with instruments that will be ludicrously simple in their construction

I have received a letter from Prof Gage on the subject of Telephony, in which he suggests a method of increasing the amplitude of the electrical undulations in a manner that had already occurred to me in a somewhat different form. He suggests placing a light spiral of insulated copper wire upon the membrane in Fig I in place of the steel spring. See Fig II

Fig II



m is the membrane and w w' the wire coiled upon it and b a small battery for passing a current through w w'. The wire w w' can be vibrated in front of A. Fig 1 instead of the steel spring and the stronger the battery power b Fig II the greater the audible effect at z Fig 1

I think the idea a very valuable and perfectly feastible

Noted by A G B. Aug 5th
Copied by M G H. Aug 10th 1876.

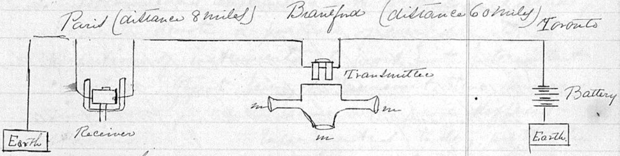
Brantford Ontario
August 10th 1876.

The experiments last night were very satisfactory as demonstrating the power of the undulatory current to travel any distance at the same time the experiments show certain difficulties we shall have to contend with in disturbances upon the line itself The atmosphere seems to be in a curious

electrical condition - affecting the working of the lines

The moment I put my receiving instrument to my ear I heard perfectly deafening noises proceeding from the instrument even when there was no battery on the circuit. Explosive sounds like the discharge of distant artillery were mixed up with a continuous crackling noise of an indescribable character. In spite of these disturbing influences I could hear vocal sounds in a far away sort of manner - and when there was singing the air was distinctly manifest

Fig I



The battery we used was in Toronto fifty-eight miles from Paris. Transmitting Instrument was in Brantford - and the Receiver in Paris - eight miles distant

Our first experiment was with "low resistance coils" on our instruments - and, as I said, the vocal sounds were very faintly audible in Paris - the crackling noise being very loud indeed. I telegraphed to Brantford (by

another line) telling the operator to change the electro-magnet upon his instruments so as to place a "high resistance" coil

At the same time I made a similar change in Paris. The vocal sounds then came out clearly and strongly, and the crackling noises were not nearly so annoying though they still persisted.

Various songs were sung in Brantford all of them being recognized at once in Paris - and I even recognized the singers by their voices. The operators were Mr. Griffin, Mr. David C. Bell & my cousin Miss Lilly Bell. My father had made some engagement - so he told me he could not be present - And yet one of the voices I heard was so like my fathers that I telegraphed to enquire the name of the singer. It was my fathers after all.

Words and sentences uttered in Brantford in an ordinary conversational key - with the voice scarcely raised above a whisper were audible in Paris - but the articulation was in most cases unintelligible. I recognized at once "To be or not to be that is the question" &c and "Do you understand that" but sentences with which I was unfamiliar were not

understood.

The words of the songs were all intelligible to me – as I happened to be acquainted with them – with the exception of one. "Maggie May" was sung by Mr. Griffin and other voices joined in the chorus. I could hear the combination of voices as distinctly as the single voice.

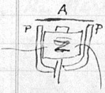
Noted at Brantford Ontario by
A. Graham Bell Aug 11th 1876
Copied by M. G. H. at Boston Aug 15th

Tuesday Sept. 12th 1876

1. Recommenced experiments with Mr. Watson yesterday. We are to devote a portion of every day to the perfection of instruments to work with intermittent current. Object being to transmit two messages simultaneously on the same wire from different stations. Experimented to-day with intermittent current — nothing new to be noted.

2. Experiment with undulatory current.

Fig I



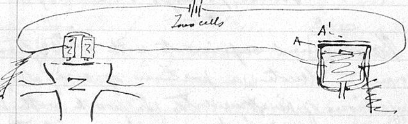
I discovered to-day that the vocal sounds audible from the Receiver Z, are intensified to a great degree when the armature A is not allowed to touch the poles PP but is held about a millimetre from them.

Fig 2

3. Mr Watson discovered that the sounds were similarly intensified when a second armature A' was laid upon the first A which latter was in contact with PP as before.

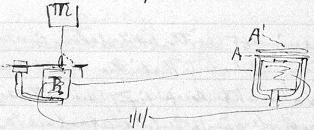
4. The sounds were clearly audible when a pile of armatures A' A^2 A^3 &c were laid on the first armature A. The maximum loudness was obtained with only two armatures as in Fig 2.

Fig 3



5. Mr Watson sang and spoke with his mouth close to A' Fig 3. The sounds were faintly audible from Z.

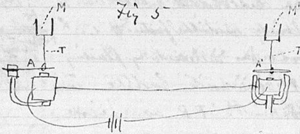
Fig 4



6. The membrane M (Fig 4) of an ordinary "Thread Telegraph" was connected by a thread T with the spring of ~~one of~~ my Receivers R. Upon singing & speaking

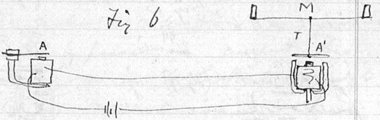
into M the sounds were faintly audible from A'.

Fig 5



7. Membranes M & M' (Fig 5) were fastened by threads TT' to the armatures A A'. Upon singing into M the sounds were faintly audible from M'; and upon singing into M' the sounds were faintly audible from M.

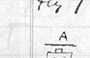
Fig 6



8. The armature A' (Fig 6) was fastened by a thread T to the centre of the membrane M of a tambourine. The diameter of the membrane M was about 10 or 12 inches. Upon plucking the armature A a sound was audible from M when it was held away at arms length. This is the loudest sound yet heard with the undulatory current.

9. Experiments were continued using the same instrument A (Fig 6) as transmitter but varying the Receiver. ~~The~~ a Armature A (Fig 7) was held in front of single pole electromagnet E. Plucking plainly audible when A was made of sheet steel or iron. Sound very faintly audible when of thicker iron than could be called "sheet iron".

Fig 7

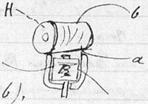


10. Empty helix H (Fig 8) of insulated iron wire was laid on Receiver R. Sound plainly audible from H.

Fig 8

11. The sound was increased by placing a wrought iron nail inside the helix H.

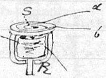
Fig 8



12. No difference observable when a single cell of battery was connected with the wires (a, & b).

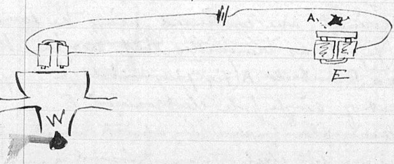
The helix H was made of No 38 (?) wire & necessarily had a high resistance. The experiment should be repeated using a stronger battery on the circuit a H b.

Fig 9



13. A flat spiral S (Fig 9) of insulated copper wire was used as an armature for the receiver R. Upon placing the ear closely against S a faint sound was audible which was not intensified by crossing a b, or by connecting them with the poles of a battery.

Fig 10

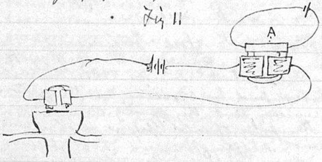


14. An ordinary electro-magnet E (Fig 10) had closely applied to its poles an armature A. When Mr. Watson sang into (W) E. his voice was audible (faintly) from A even when the armature A consisted of a piece of iron a quarter of an inch thick. This looks as if the vibration which is audible is a molecular movement — and not a vibration of the armature as a whole.

Thought.

15. If the sound audible from A (Fig 10) is the result of molecular disturbance — the amplitude of the molecular vibrations may probably be increased by passing a current through the armature — as in De la Rive's experiments — see Fig 11 for proposed experiment.

Fig 11



Noted by A. G. B.

Tuesday night, Sept. 12th 1876

Wednesday Sept. 13th. 1876

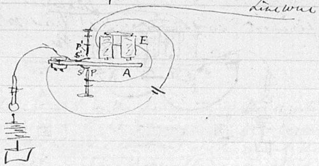
1. Experiment No 15 (page 49) tried this evening.

Fig I

Upon plucking the spring S the sound was plainly audible from A while in close contact with the poles of the electro-magnet E. The sound ~~was st~~ proceeding from A was still more decided when a piece of paper was introduced between the armature A and its electro-magnet. No effect was produced by the passage of a voltaic current through A. At first I fancied that the pitch of the sound audible from A was lowered slightly when the current was passed through the armature but repetitions of the experiment aided by Mr. Watson convinced me that it was the result of imagination.

2. Mr. Watson & I have been discussing to-day various modifications of the Instruments to work with the intermittent current. In order that the vibratory circuit breakers should be operated satisfactorily – it is evidently necessary that the spring armatures of the Receiving Instruments should possess greater weight & be made of much stiffer springs. It seems to us also that the larger & stiffer the vibratory armatures of both Transmitters & Receivers can be made the less likely will it be that their pitch should be changed. The rigid contact points of the old Transmitters will evidently not do for heavy armatures. We propose to make a Transmitter like that shown in Fig 2: The fixed point P makes & breaks contact with a spring S attached to the armature A. This make & break is for the local circuit. The contact point P' makes & breaks contact with a spring S' which is insulated from the armature A. This make & break operates for the main circuit and is

Fig 2



entirely independent of the local circuit.

Noted by A.G.B.

T.A.W. Sept 14th 1876

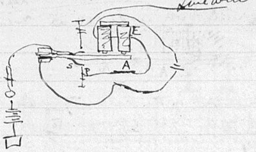
Thursday Sept. 14th 1876

1. Instead of having the instrument shown in Fig 2 (page 51) constructed to-day Mr. Watson & I have been discussing various improvements suggested in the instrument. We have also visited the Institute of Technology for the purpose of studying closely the apparatus ~~there shown~~ invented by Helmholtz. In all the forms of instruments we have used or have seen employed by others — there is one defect which seems to us to weaken the vibrations of the armature of the transmitting instruments — and that is that the power of the electro-magnet is always ~~used~~ opposed to the normal vibration of the armature.

For instance — ~~it is when~~ the spring S comes in contact with the point P (see Fig 2 page 51) when the armature A is normally moving away from the electro-magnet E — but it is just at this moment that the magnet begins to attract the armature A. Hence the power of the magnet is used at first to stop the ~~out~~ outward motion of A. ~~After a short time the attraction of the magnet o~~ and it is not until this is accomplished — that the attractive power is utilized in moving A.

There is evidently then a waste of power. If this is sought to be prevented by screwing back the point P the contacts between P and S become very short — and thus again the power of the magnet E is weakened.

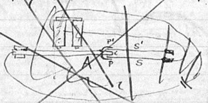
Fig I



2. If it could be so arranged ~~so~~ that the contact between S & P should not take place until the armature A has made its full excursion from the magnet E and is just about to swing back; and that the contact should continue so long as the armature A is normally moving towards E; and that the contact should be broken when the armature A has normally reached the limit of its excursion towards E —— we should then have the attraction of the magnet co-operating with the normal motion of the armature which would then be kept in uniform vibration.

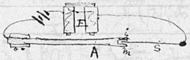
3. Why should not the principle of the vibratory circuit-breaker come into play? Let the armature strike a body of *slower vibration* than itself.

Fig 2



Over

Fig 2



Let a notch be cut in the extremity of the armature A large enough to allow the end of a light spring S to fit loosely into it. One side, m, makes metallic contact with S but the other side i is insulated. Let S have normally a much slower rate of vibration than A. Then upon plucking A so as to set it in vibration - we should find that its vibration continues, and the following should be the mode of its action:

As A advances towards E the point m strikes S and carries it with it. As the normal rate of vibration of S is slower than that of A, S tends to lag behind and therefore presses firmly against m all the time the armature A moves rapidly towards E. ~~But~~ The magnet E is thus excited during the approach of A ~~and~~ assisting the motion: But as A ~~begins to reach~~ nears the limit of its excursion it begins to move more slowly and the spring S having acquired impetus from m ~~[illegible]~~ flies over to i breaking the circuit. The armature A then swings back ~~[illegible]~~ & during its rapid motion from E the spring S (having a slower rate of vibration than A) tends to lag and thus remains against the insulated point i until the armature A is nearly ready to swing back when it again flies over to m re-closing the circuit.

Fig 3 L.W.

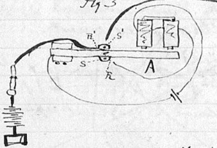
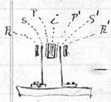


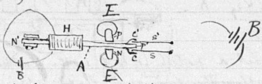
Fig 4.



4. Figs 3 & 4 show an arrangement for local & main circuit. R & R' are rings or rather bridges of metal for the springs S and S' to make contact with. The iron i, of the armature A is insulated on both sides by means of ~~paper~~ pieces of paper P, P'. Experiment will show the best part of the armature to which to attach the circuit breakers.

5. Another idea. Use polarized armature, and utilize the repulsive power of the magnet.

(Fig 5)



Place the armature A inside a ~~coil~~ helix H which is excited by a local battery B. The armature A then becomes magnetic and its poles are P' & N'. Now if it can be so arranged — let the ~~exact~~ current from a local battery B' pass through the electro-magnet EE ~~coils~~ so as to make the poles P & N when the spring S' touches the contact wire C', and ~~reverse the poles when~~ the opposite when S touches C.

The action of the apparatus would then be as follows. Pluck the spring N'P' so as to set it vibrating. Let S' touch C'. Then the pole P' would be attracted by N and repelled by P. When P' has nearly reached the limit of its oscillation towards N — the springs S & S' fly over against C and P' respectively — and the poles P and N are suddenly reversed — ~~P~~ ~~P~~ N therefore repels P' and P attracts it.

Query — Would the vibration of A occasion an undulatory current in the coils of the helix H?

The current passing through the electro-magnet EE would be an intermittent & reversed current with the breaks of the circuit so short as almost to constitute it a pulsatory & reversed current.

Fig 6

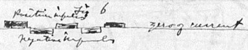
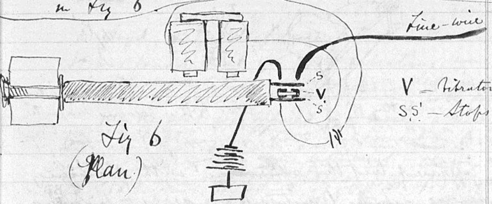


Fig 6 shows a graphical representation of the current.

6. It seems to me that for practical purposes it is unnecessary to use such a complicated arrangement as that shown in Fig 5. Such an arrangement is interesting as affording a theoretically perfect vibration — still for practical purposes I doubt whether it offers any greater ad-

vantages than that shown in Figs 2, 3, & 4.

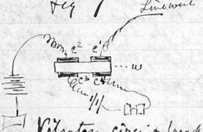
If Mr. Watson approves of the idea I shall have an instrument constructed tomorrow like that shown in Fig 6.



V — Vibratory circuit-breaker
S S' — Stops against which V vibrates.

Fig 6
(Plan)

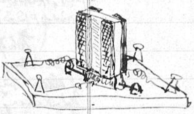
Fig 7



Vibratory circuit breaker.
W — thin piece of wood
$c^1 c^2 c^3 c^4$ — Pieces of copper or platinum foil.

Plan of V.C.B.

Fig 8
Elevation of V.C.B.

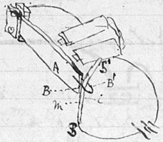


Noted by A. G. B.
Sept. 14th 1876

T. A. W.

Friday Sept. 15th 1876

Fig I



1. Experiment tried this ~~afternoon~~ evening with promising success. To the Armature A was soldered a bridge BB' of copper wire. A german silver spring SS' was intro-duced into the space between the wires B and B'. One side i of the spring SS' was covered with paper so as to be insulated and the other side m presented a metallic surface to the wire B. Upon plucking the armature A it was thrown into continuous vibration, and the spring SS' partook of the motion.

Mr Watson ~~had~~ occupied the greater part of the afternoon in the construction of the instrument and I ~~then~~ visited the South Boston Blind Asylum with McKinsey — dining with him afterwards so that it was quite late before we could try the instrument. The result seemed promising although our first attempt was a failure.

Mr Watson had constructed a rocker like that shown in Fig 8 page 55 — but it was so large & heavy that it could not be moved by the armature. A light german-silver spring however as in Fig I (page 56) gave evidence of vibration but it was difficult to adjust the spring. It seemed to alter the pitch of the armature when it was adjusted a mere hairsbreadth. The best effect was obtained with the end S' projecting about half an inch above BB'.

Noted by A. Gr. B.
Sept. 18th 1876

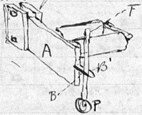
Saturday Sept. 16th 1876

1. Experiments with apparatus described on preceding page continued this afternoon.

Springs of German silver of various sizes were employed, & the distance between the wires B & B' ~~varied~~. It was found that the best vibrations were obtained when the space B B' was reduced to a slit just wide enough to admit the spring S S' without touching both ~~sides~~ wires B B'.

When the slit was reduced to ~~a mere~~ a minimum it was found that strong vibrations were caused in A when springs of all shapes & sizes were introduced – even a simple piece of copper-wire used in place of SS' proving sufficient to sustain the vibrations. In these cases the wire B' was insulated by means of a piece of paper so that the spring SS' should not come into metallic contact with it. By sliding the spring or wire SS' upwards or downwards it was found that there was a point ~~where for~~ each spring – where the maximum effect was produced.

(Rp.



(Fig 2)

2. A ~~flat~~ German silver spring F P was suspended so as to form a pendulum, and an iron nut was fastened to the extremity of F P so as to give the pendulum a slow rate of oscillation. It was found that in this case the pendulum F P controlled the motions of A instead of vice-versa as before. It is evident that there is a struggle between the vibrator A and the vibrator F P – and which ever of the two possesses greater inertia will control the movements. In the case shown in Fig 2 it was found that the motion of F P was very rapid (to the eye) when the wires B B' struck it at a point near P. The oscillations of F P became slower

as the wires B B' struck the pendulum further & further away from the weighted extremity P.

Query Why should not such an arrangement as this be used to work a clock without any works at all?

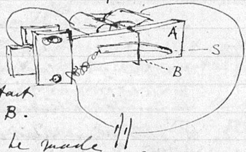
Thoughts.

3. One objection to the use of springs &c like those shown on pages 56, 57, is — that adjustment screws would be necessary so as to regulate the position of the spring as it affects the pitch of the armature.

Why should not the spring be itself carried by the armature and be part & parcel of it thus avoiding any tendency to affect the pitch? We shall try arrangement like that shown in Fig 3.

A (the armature) has the whole of one side covered with insulating material so that there is no metallic communication between S and A ~~at~~ until the spring S comes into contact with the copper bridge B.

Fig 3



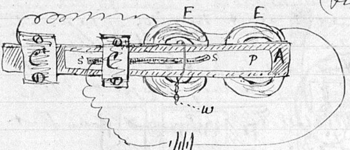
Connections could be made on one side of armature for local & on the other for main circuit.

Noted by A. G. B.
Sept. 18th 1876

Monday Sept. 18th 1876

1. First day we have commenced experiments in the morning. Not having materials at hand for soldering we were unable to try experiment 3 (page 58) as shown in the illustration. Mr Hubbard came in this morning & seemed interested in the experiment so we arranged an instrument as shown in Fig I

(Fig I)



A armature. ~~D~~ P strip of white paper.
SS' german silver spring in metallic contact with C.
The sheet of paper P was broad enough at C to prevent the armature A from coming into metallic contact with C.
W. A copper wire twisted round the armature A so as to confine the ~~vibrations~~ spring SS'.

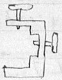
Upon plucking A it continued vibrating in front of the electro-magnet EE and the spring SS' was also thrown into strong vibration. This shows that the idea will work.

We propose having an instrument constructed like that shown in Fig ~~8~~ 7 page 61 ~~8~~ after having experimented with Helmholtz' tuning forks in the manner shown in Fig ~~2~~ 6 so as to discover the best arrangement of springs.

Ober

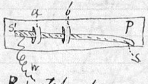
2. We have obtained the loan of one of the large tuning-forks used in Helmholtz' experiment and propose fixing an adjustable clamp upon the prongs like that shown in Fig 2.

Fig 2



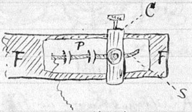
A piece of pasteboard like that shown in Fig 3 — is to be clamped on to the prong as shown in Figs 4 and 5.

Fig 3.



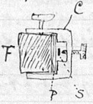
P pasteboard
SS' german silver spring, adjustable through the loops a b,
W Conducting wire

Fig 4



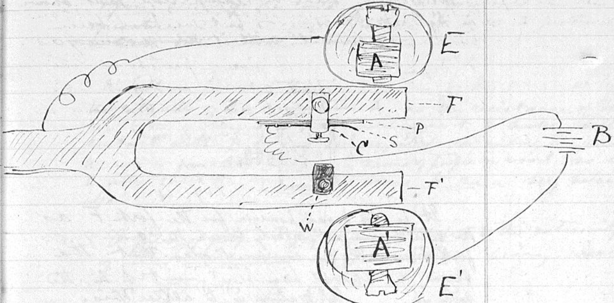
F Prong of tuning-fork
P ~~Paper~~ Paste-board } shown in Fig 3.
S spring }
C – Clamp shown in Fig 2.

Fig 5



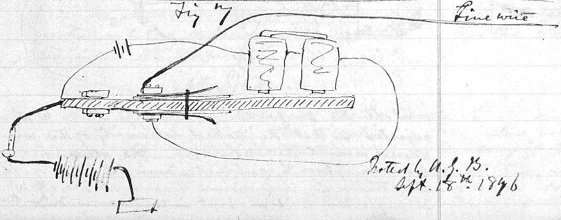
F Prong of fork
C Clamp shown in Figs 2 and 4.
P paper } shown in Figs 3 & 4.
S spring }

Fig 6



C Clamp shown in Figs 2, 4, & 5.
P Paper } shown in Figs 3, 4, & 5
S spring }
FF' prongs of fork
W - weight as a counter-poise to clamp C
EE' Coils of Electro magnet
AA' Adjustable pole-pieces
B. Battery.

Fig 7

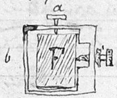


Noted by A. G. B.
Apt. 18th 1876

Tuesday September 19th 1876

1. Mr Watson made a clamp like that shown in Fig I this morning — but we have been unable to experiment with it ~~this morning~~ as yet.

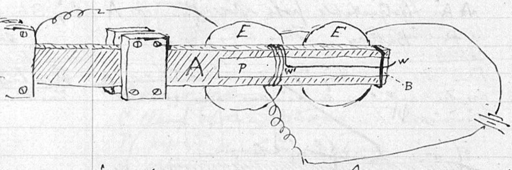
Fig I



It is too broad however for the fork F as the side b does not nearly touch the side of the fork F. We are convinced also that the screw, a, should have been inserted in the side b. Mr Watson is to alter this.

2. Experiments resumed with spring armature A Fig 2. A bridge of copper-wire B was soldered to the extremity of the armature A and a slip of paper P was pasted over the armature so as to

Fig 2



insulate the surface. A copper wire W W' was adjusted so that the naked extremity of the wire passed beneath the bridge B. — ~~The other~~ wire was secured in place by coiling the insulated part of the wire three or four times round the armature at W'. Upon plucking A it was kept in continuous vibration

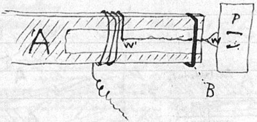
by the intermittent contacts of W and B.

2. Upon sliding the coils of wire W' forwards on the armature so as to cause the ~~the~~ end W to protrude a much better vibration was occasioned.

3. Mr Watson favored the protrusion of the wire W beyond the extremity of the armature A as the resistance of the air to the motion of W would cause it to make better contact with B; and ~~he~~ I suggested expanding the point W into a fan-like shape by means of paper or wood so as to better catch the air. This seems to me a very valuable idea:

4. A piece of paper P (Fig 3) was attached to the extremity of the wire WW' — connections being arranged

Fig 3.



as in Fig 2. The vibrations of A (Fig 3) at once became intense. This was by far the most satisfactory experiment yet made. Upon clipping down the paper P — the amplitude of the vibrations of A and of P became greater until a maximum was reached. Farther clipping diminished the amplitude.

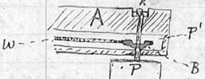
Thoughts.

5. This plan of Mr Watson's seems to me to be an excellent way of making the vibrations of ww' slow without increasing either the weight of the wire ww' or making it longer.
If the inertia alone of the wire ww' is to be utilized we must either make it very heavy — in which case of course its position &c will require determination as it will affect the

pitch of the armature: — or we must make it very long and slender — in which case it would be delicate & liable to get out of order. By utilizing the resistance of the air we can make the wire or spring W W' thick enough to stand wear & tear, and ~~short enough~~ as short as we please. So long as we have a good surface exposed to the air the instrument should work. Of course however the ~~surface~~ proper extent of surface to be exposed must be determined upon for the resistance ~~of~~ offered by the air to the motion of P will also affect the motion of A, and hence affect the pitch.

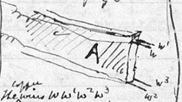
5. Forms of apparatus shown in Figs have suggested themselves to me.

Fig 4



R P Rocker of copper pivoted at R in the armature A.
Bridge B insulated from A by P'.
W. wire connecting B with battery.

~~Fig 6~~
Fig 5

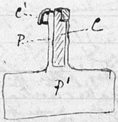


The copper wires W W' W² W³ are insulated from the armature A and from one another.

Fig 6

PP' Paper
CC copper slips

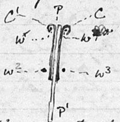
~~Fig 7~~ Fig 7



CC' copper slips
PP' paper.

~~Arrangement upon~~

Fig 8.



Combination of parts shown in Figs 5, 6 & 7.

~~Fig 9~~

Noted by A. G. B.
Tuesday Sept. 19th 1876

~~Wednesday~~ Tuesday Sept. ~~20~~ 19th 1876
(addendum)

1. I neglected to record some suggestions concerning the transmission of vocal sounds. I have not obtained as satisfactory results (so far as distinctness is concerned) as those obtained by Sir William Thomson & Prof. Watson at the Philadelphia Exhibition. Upon thinking over the differences between the instrument used by him & ~~the~~ those employed by ourselves here — Mr. Watson & I have come to the conclusion that the material of the armature used may be of importance. We have been employing thin soft iron (Tagger's Iron) — which ~~we now remember that the~~ has become oxidized. The armature of the Philadelphia instrument is made of blue clock-spring. We tried the effect of using clock-spring last week with much better results than those obtained with the iron — but the distinctness was very slightly improved. Still we are of the opinion that it was improved — though of course

there is nothing to show that this was not the result of a mere change of armatures — ~~and not instead of the substitution~~ instead of being the result of the substitution of steel for iron.

— 2. It is a question in my mind whether the imperfect effect of the articulation may not be due to the large size of the armature. It covers a large portion of the membrane ~~in order to reach~~ as it must be long enough to extend opposite both poles of the magnet.

Now ~~the~~ one of the Instruments in Philadelphia has a very small piece of clock-spring (no larger than my thumb-nail) glued to the centre of the membrane - so as to vibrate in front of the pole of a ~~[illegible]~~ straight electro-magnet.

So far as I can recollect ~~the most~~ I think that I used to obtain the most distinct sounds by using that instrument — and the loudest sounds by employing the other — consisting of the double-pole magnet. I do not know which instrument was employed by Sir William Thomson. Certainly a small piece of spring fastened to the centre of the membrane would interfere far less with its vibration than a large piece extending right across.

— 3. Mr Watson suggests also that the small size of the space ~~between the~~ contained in the mouth-piece has something to do with a proper vibration of the membrane.

He suggests a box-like arrangement like that in Reis' Telephone.

4. He also suggests ~~to~~ making an attachment to a Reis' Telephone for making & breaking the circuit upon our new principle. He thinks that not only the pitch but the quality

of the ~~sound~~ voice would be heard at the Receiving End with an intermittent current — if the duration of the make could be made proportional to the density of the air — during the continuance of the sound. That is — when there is a great condensation long contact — a slight condens. — slight contact.

He thinks that a long contact is required to thoroughly magnetize the magnet at the Receiving End — so that changes in the duration of the ~~different~~ successive contacts would occasion analogous changes in the strength of the successive attractions of the distant electro-magnet — so that the armature would be constrained to copy the form of the original vibration — & emit ~~the~~ a similar sound.

The idea looks feasible — though I have very strong doubts of the success of the plan on account of the inactivity of the Receiving Electro-magnet during the breaks of the circuit.

It is not at all improbable however that the plan may succeed.

Noted by A. G. B.

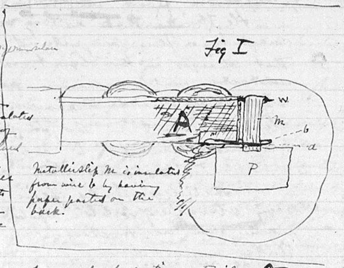
Wednesday evening Sept. 20th

Bell

Wednesday Sept. 20th 1876

1\. Experiment tried this morning as illustrated in Fig I.

A – armature
m. metallic slip of german silver movable about the wire w.
a & b two wires limiting the oscillations of m. a & b are insulated from A by means of pieces of paper p' glued to the armature A.
P piece of paper attached to m – to serve as a fan & offer resistance to the air.



The instrument worked satisfactorily. ~~Upon~~ The paper however was so large that it divided into nodes while vibrating.

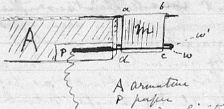
2\. The paper P was ~~successively~~ cut away ~~smaller & smaller~~ until it was entirely removed – with ever increasingly ~~good~~ better effect.

It was evident that the metallic surface m offered sufficient resistance to the air and that all the surface exposed below a only interfered with the ~~motion~~ closeness of contact of m & a.

The resisting surface should be above a so that the extremity of m may have the maximum amplitude consistent with the vibration. * (See addendum)

3\. A metallic slip m, (Fig 2) of german silver was made (~~Fig 2~~).
Breadth (a b) ~~eight~~ 3/8 inch – Length bc ½ inch.
Vibrations ensued but it was difficult to adjust the wires w w' – ~~on~~ on account of the length of surface, cd, liable to come in contact with w.

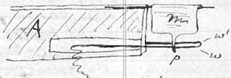
Fig 2



A armature
P paper
w w' wires limiting motion of
m metallic slip of german silver insulated from w' by paper pasted on back

4. The metallic slip m Fig 2 was cut to a point P as in Fig 3. Very forcible vibration of the armature A caused especially when the wires w w' were brought very closely together.
No rattling sound was audible but a pure musical note of a very agreeable quality.
~~The best~~

Fig 3

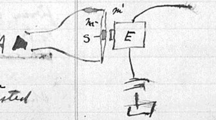


P insulated from w' by paper pasted on back.

5. The best effect was produced when the wires w & ~~w~~ w' seemed to be ~~...~~ in actual contact with P all the time. Either the natural elasticity of the paper pasted ~~upon~~ the back of P sufficed to make P make & break contact with w — or the spring of the of the wires w w' attained the same end.

6. A piece of indian rubber was glued to the back of the point P and the wires w & w' brought into actual contact with P. ~~The~~ Very forcible vibrations were occasioned in the armature A although I think that Experiments 4 & 5 ~~...~~ gave the best results.

Fig 4



7. ~~Experiment with Undulatory Current.~~
A circular piece of blue clock-spring S was glued between two membranes m m' of goldbeater's skin so as to be in the centre opposite the pole of a straight electro-magnet E — as suggested

on pages 64-65 (Notes 1 & 2).

Upon singing & talking into A the sounds audible from the Receiving Inst- were fully as loud as when a large armature & double-pole magnet was employed. The armature in this case was just the area of the pole of the electro-magnet in front of which it was placed - (diameter 3/8 of an inch) The articulation however was just as indistinct as before.

Shall try single membrane - and experiment as suggested on page 28 (Wednesday July 12th)

Noted by A. G. B.
Thursday Sept. 21st 1876

(Addendum)
Thursday Sept. 21st 1876

1. Upon showing the record of yesterday's experiments to Mr. Watson he found exception to the ~~[illegible]~~ deductions made from experiments 2 (page 67) —

Viz - that all the surface P exposed to the action of the air below a interfered with ~~the [illegible]~~ contact of m and a; and that the resisting surface should be placed above a to produce the best effect.

The point at issue will be seen by a glance at Figs 1 and 2 (page 70).

A is the armature to the extremity of which is attached a rod or wire ~~[illegible]~~ of metal b moveable upon an axis a and carrying a card or other light ~~[illegible]~~ material exposing a large surface S to the action of the air.

The object of the arrangement is to secure a firm contact between b and w during the motion of A from the spectator and entire absence of contact ~~[illegible]~~ during its motion towards him.

It seems to ~~[illegible]~~ me that the arrangement shown in Fig 2 will achieve this end much better

(Noted Sept 22nd 1876 [illegible])

than that shown in Fig I — but Mr. Watson seems to think otherwise.

Fig I　　　Fig 2　　　Fig 3.

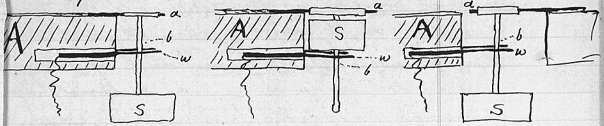
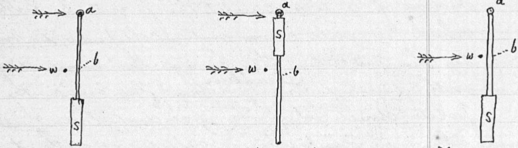


Fig 4　　　Fig 5　　　Fig 6



Figs 4, 5, & 6 are end views respectively of the arrangements shown in Figs 1 2 & 3. In Figs 3 & 6 the axis a is fixed, the wire w alone moving. In Figs 1 & 4, 2 & 5, the axis a moves in the same direction and at the same rate as w.

He thinks that when w strikes b. Fig 1. the resistance of the air opposes the motion of S which is placed at the end of the lever a S - so that w acts upon b at a mechanical disadvantage, while in Fig 2 w acts upon b at a mechanical advantage, hence the contact between b and w in Fig 1. must be firmer than in Fig 2.

Now I would readily admit that such is the case if the point a were fixed and the point w alone moving as in Fig 3. But it seems to me that the motion of the point of suspension a very materially alters the case. In Figs 4 & 5 end views are obtained

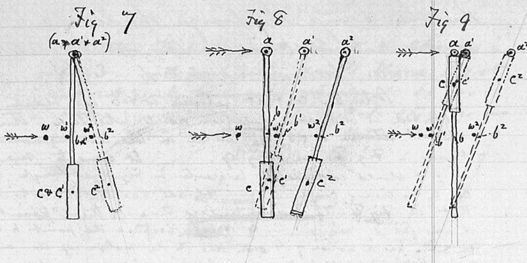
of the instruments shown in Figs 1 and 2. It must be remembered that not only does the wire w advance in the direction of the arrowhead but that the point a advances in the same direction and at the same rate of speed

Now the motion of a tends to turn the point a around the centre of pressure c as shown in Figs 8 and 9 and it will be observed that the motion of a to a' causes the point b with which w will come into collision to move in the one case (Fig 8) in the same direction with w and in the other (Fig 9) in the opposite direction. It is evident then that when w comes into collision with b the firmness of the contact will (in Fig 8) be equivalent to the velocity of w - minus the velocity of b while in Fig 9 it will be w plus b.

Then again there is another advantage that the arrangement in Fig 9 has over that in Fig 8 - namely in the time of contact

We want the contact to begin at the moment the armature begins to move towards the magnet (that is, the moment the point a (Figs 8 & 9) moves in the direction a') & stop the moment it returns -

Now in Figs 8 & 9 we can compare the rates of motion in the two cases. The point



a moves successively to a' & a² and in both cases the point w moves in the same direction and at the same rate of speed.

Now it will be seen that in the arrangement Fig 9. the wire w will come into contact with b when a has moved a very small distance a a' while in that shown in Fig 8 it will not strike b until a has travelled a much greater distance. The rate of motion of the points a & a' is supposed to be the same in Figs 8 & 9 so that the contact between w & b will take place much more suddenly in Fig 9 than in Fig 8. Indeed the more the center of pressure c is depressed below w the longer is contact between w and b delayed, and if the lever a c (Fig 8) were made very long contact between w & b would be avoided altogether unless ~~w & b~~ the amplitude of a's vibration could be made very great. Upon

the other hand the longer the lever a b Fig 9 is made the more quickly will contact be made between w and b

After the contact between w & b has been effected it becomes a question as to whether the contact between w & b ~~is~~ continues greater in the arrangement shown in Fig 8 or Fig 9. It seems to me as if it should continue to be greater in Fig 9 although I am by no means certain. At all events it is evident that in Fig 8 the pressure is less than if the point a was fixed, and in Fig 9 greater; because the point b ~~in~~ ~~Fig 8 b~~ has a motion of its own due to the motion of a, and this motion in Fig 8 is in the same direction with that of w, while in Fig 9 it is in the opposite direction. It may be however that no advantage is gained in firmness of pressure in using arrangement in Fig 9 — for certainly the pressure would be less than that in Fig 8 if the point a were fixed. However one great advantage is the quickness of contact.

Noted Sept. 23rd 1876
by A. G. B.

Thursday Sept. 21st 1876

1. Experiments. A metal ~~tube~~ rocker m i (Fig I) was attached to an axis a upon the armature A. m made metallic contact with A and i was insulated.

Fig II shows side view of same arrangement.

The armature A vibrated but with little amplitude. The result though unsatisfactory in some respects — showed that such an arrangement would work.

Fig I

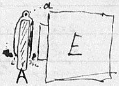
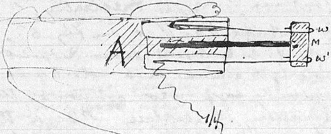


Fig II

2. Mr. Watson tried arrangement like that shown in Fig 3 — with much better results than last but not nearly ~~such good arrangement~~ so good as has been obtained. The metal slip m made —

Fig 3



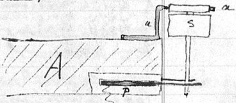
metallic connection between the two wires w & w'. Quite satisfactory vibrations were obtained.

3 If theory broached on pages 70–3 is correct we should obtain best results by placing w (Fig 2 page 70) very low and S very high up.

Tried arrangement shown in Fig 4.

Could not get satisfactory vibration. ~~Fig~~ The upright U however had a decided motion of its own. Experiment inconclusive.

Fig 4



4 Shall try experiment like that shown in Fig 5.

m. Metal flange extending along the underside of A upon axis a a.

b Lacy style vibrating between w & w'. w is for the local circuit + w' for the main

Fig 5

Noted by A. G. B.
Sept. 20th 1876

Friday Sept. 22d 1876

1. Spent last night in Haverhill so could not be here in time to begin early. Mr. Watson occupied time in placing room in order, and in making new connections — & in taking down & cleaning battery cells.

2. Tried experiment (No 4) suggested yesterday. Apparatus constructed like that in Fig 5. Could not get vibrations from it at all. We both think that we have been wandering off upon a track that it is unnecessary to explore — and that the resistance of the air — does not prove so much of an auxiliary as we have anticipated. We do not think that any better or simpler arrangement can be well be conceived than ~~that~~ that shown in Fig 7 page 61.

3. Repeated experiment No 7 page 68 - placing a reed-box in front of the mouth piece & talking into the ~~...~~ reed-box. We are both inclined to believe that the sounds at receiving-end were more distinct — and that perhaps the enlargement of the cavity in front of the membrane may make the sounds more distinct. Propose borrowing Cone of Phonautograph from Instit. of Technology.

Notes by A. G. B.
Sept. 26th 1876

Saturday Sept. 23rd 1876

1. Experiments with Mr. Gage's apparatus. Nothing new.

2. Willie Hubbard made his appearance today and gave me particulars of experiments ~~with~~ made at Centennial Exhib. by Sir William Thomson.

The single pole & double-pole magnets were ~~both~~ used alternately and with equal effect — so it is evident that we were wrong in ascribing the success to the use of the single-pole magnet. Membrane moderately tight. Battery-power 12 cells of Carbon freshly put up for the occasion. The transmitting telephones were used alternately. As soon as one became hot it was removed & the other one used. Here then probably is the cause of success — the powerful battery.

We shall try this. Perhaps too it might be well to try magnet with thick wire & low resistance.

Prof. Watson spoke loudly into the transmitting Inst.

Shall try thicker membrane — larger cone and stronger battery.

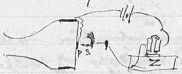
Noted by A. G. B.

Sept 24th 76

Monday Sept. 25th 1876

MG Experiments with intermittent current to use membrane.

Fig I

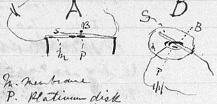


P. Platinum disk.
S. Screw.
Poor effect at Z. Crackling sound due to imperfect contacts between P & S.

Fig 2

A

B



m. membrane
P. Platinum disk
B. Metal bridge
S. Spring insulated on its lower surface

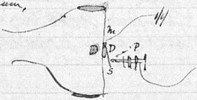
1. Arrangement as in Fig I poor effect — crackling sound but no musical note.

2. Arrangement in Fig 2 (A or B). ~~poor effect~~
Spring S insulated on lower surface — poor effect — better than 1. Occasionally loud musical note from receiver but generally a "frizzling" ~~crackling~~ sort of sound

3. (Fig 2) Spring S. insulated on upper surface same effect as last.

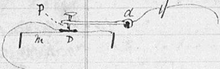
Fig 3.

4. (Fig 3). D disk of platinum,
S spring soldered to disk.
P. Platinum point.
m. membrane.



Effect — "frizzling" sound
Occasionally loud musical note — especially when pitch of membrane was used.

Fig 4



5. (Fig 4) P—Platinum point resting by its own weight upon ~~membrane~~ disk D.

Best effect produced. Either loud musical note or continuous current. Occasional frizzling. Lever P a too heavy.

Think that the arrangement in Reis' Telephone will give best results. Intend to make m of india rubber ~~—~~ & other arrangements ~~at~~ à la Reis.

Rheotome

Fig 5

6. Tried the relative effect of having the point - P - carried by the armature A or fixed - exteriorly to it.

In both cases obtained good vibrations, but obtained best results when point P is fixed. Beginning to be afraid that the arrangement from which we have wandered (Fig 2 page 51) is after all the best. Amplitude of vibration obtained from A 3/8 inch with 4 cells.

Undulatory.

7. Upon showing Telephone to Mr. Kinsey was surprised to find utterance very distinct especially when high notes were employed. Mr. Kinsey understood readily the majority of sentences that were spoken in a high pitched voice. Same sentences unintelligible in low tone — although the sounds were louder.

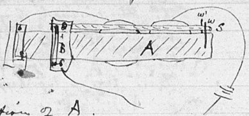
Battery power 4 cells — newly set up in splendid working order.

Noted by A. G. B.
Sept 27th 1876

Tuesday Sept. 26th - /76

1. Intermittent. (Fig I)
A armature insulated from B.
S spring in metallic contact with B and insulated from w'.

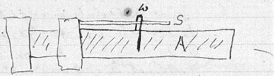
Fig I



Effect - slight vibration of A.
S vibrated so as to have a nodal point where w & w' struck it.

2. (Fig 2) Similar arrangement to last but wire w about centre of armature.

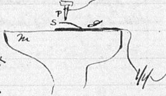
Fig 2



Could not get more than a trace of vibration excepting when S projected about an inch beyond w.

3. Membrane attachment. (Fig 3)
m - membrane.
g. German silver extending from side to the centre of the membrane & glued to it.
S. Spring soldered to g.
P. Platinum point.

Fig 3



Unsatisfactory —

Undulatory

4. Tried instrument with six cells of battery — freshly made up. Articulation very distinct with high notes & occasionally distinct with low notes.

5. Tried effect of varying force of voice. The audible effects ~~were not~~ did not differ so much in loudness as the original sounds. The softest articulation seemed — at the receiving instrument — to be little inferior in loudness to the effect of the loudest articulation — ~~but~~ and I think was more distinct. A buzzing "~~or a~~" hollow" sound accompanies the loud artic.

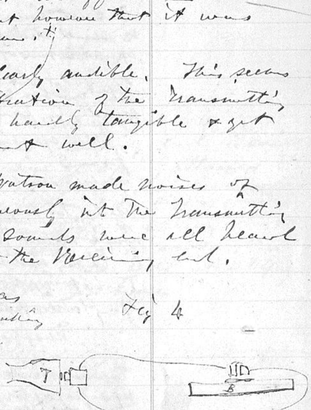
6. Tried whispering. An audible effect was produced at the receiving end — a curious soft rustling sound very difficult to detect — but both Mr. Watson & I agree in believing that an effect was audible. The sounds were so faint however that it was impossible to analyze them. †

7. Whistling was very clearly audible. This seems strange — for the vibration of the transmitting membrane was ~~not~~ hardly tangible & yet the sounds came out well.

8. Edward Wilson & Mr. Watson made noises of different kinds simultaneously into the transmitting Telephone — & the sounds were all heard without conflict at the receiving end.

9. Tried sounding box B as a Receiver. Upon speaking & singing to T the sounds were audible from B at a distance of one foot.

Fig 4



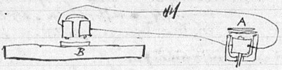
Notes by A. G. B.
Sept 27th 1876

† Mr. Watson disagrees with me. He thinks that the whispering was just as audible or nearly so as the vocal sounds. Of course he listened to my whispering which was much louder than his own. A. G. B. Sept 28th 1876

Wednesday Sept 27th 1876

1. Used sounding board as Transmitter (Fig I)
Spoke + sang &c into
Sounding box B.
Sounds faintly
audible from A.

Fig I



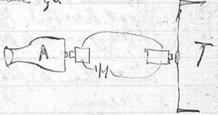
2. Tambourine used as
Transmitter Fig 2.
T Tambourine
S small steel spring
A armature of receiver.

Fig 2.

Effect. Upon speaking + singing before T — exceedingly faint sounds audible from A.
Upon speaking to A faint sounds audible from S.

Fig 3

3. Used Tambourine as Receiver Fig 3.
Sounds uttered into
A loudly audible from
T but articulation
very indistinct.



4. Experiments with Intermittent — all so unsatisfactory that there is no need of noting them here.

Noted by AGB.
Sept. 27th 1876

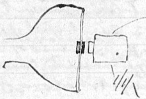
Thoughts.

5. Continued experiments show that a double armature on the Receiver increases very greatly the audible effect. Why should this be? Is there a vibration between the two armatures? Or ~~are the two armat~~ are the two armatures merely equivalent to one armature of double the thickness?

Test this matter. A correct understanding of the cause of this phenomenon may lead to improvements. Try same thing with Transmitter

Try a membrane M with two springs S S' as in Fig 4.

Fig 4



6. The loudness of the sounds at receiving end is nearly the same whatever the size of spring attached to the membrane — or at least the loudness does not vary entirely in proportion to the size of spring. Test therefore the minimum size of spring that will produce audible effect. The smaller the spring can be made the less will it interfere with the vibration of the membrane.

7. Why should not iron filings scattered over membrane do. Use double membrane containing iron filings between.

8. I forgot to state among Experiments made today that wetting the membrane did not seem to affect its vibration at all but rather improved it. Moisten with glycerine & water as in Ear Experiments

[illegible]

If small metallic surface or iron filings prove successful try to use the membrane of the human ear as a transmitter. Attach light ~~[illegible]~~ piece of iron or steel to Malleus — having removed Stapes and incus.

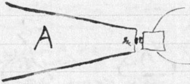
Noted by A.G.B.
Sept. 27th 1876.

Thursday Sept. 28th 1876

1. Undulatory Current

Phonautograph Cone A 
Fig I used to condense sound vibrations upon the membrane M.

Fig I



Effect — Sound barely audible at the receiving end of the line.

2. Apparatus (Fig I) ~~to~~ used as a Receiver. With intermittent current obtained loudest sounds yet heard. With undulatory current the sounds were audible — at the open extremity A of the cone ~~[illegible]~~ — some times quite loudly — ~~loudly as a~~ but no improvement in distinctness. The sounds were the loudest yet obtained with the undulatory current.

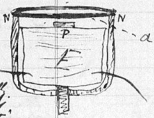
---

3. Tested difference between single & double armature on the Receiver & both Mr Watson & I are ~~a~~ certain that the double armature increases very materially the loudness of the sounds. Upon this point I also obtained the independent judgment of Mr Kinsey — and there can be no doubt about it.

We have been unable to try armature of double the thickness — but ~~[illegible]~~ I feel sure that the effect is due to the double armature & not to the thickness — and the following explanation occurs to me.

The armatures a a' are in contact with the pole N N and partake of its polarity. The armatures a a' having therefore the same polarity tend to repel one another. Now when the current traversing E becomes stronger the pole P attracts a downwards and at the same time ~~[illegible]~~ a & a' tend to repel each other more powerfully. When the current through E is weakening the armatures return to their normal position.

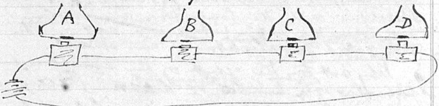
Fig 2



Thoughts.

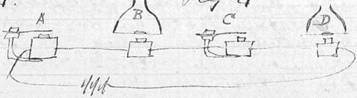
4 Try following experiment for transmitting messages.

Fig 3.



Arrange four stations A B C D as in Fig 3. Let listeners be stationed at B and D. Let transmitters be stationed at A and C. Let transmitter A transmit a message to D by sounding his signals on a horn or other instrument into A. While transmitter C transmits his message to B in similar way. Perhaps the simplest way of trying experiment would be to pluck springs as in Fig 4.

Fig 4



85

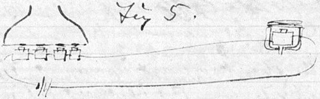
5. For the mere purpose of Transmitting Musical notes it ~~xx~~ may be well to increase as much as possible the amplitude of the ~~vib~~ inducing vibration — but for transmitting vocal ~~sounds~~ utterance, & timbre it seems to me that we are entirely on the wrong track. It seems to me that we should increase the amplitude of the electrical undulations certainly — but not by increasing the amplitude of vibration of the inducing body.

Indeed the less the amplitude of the vibration of the inducing body the more distinct should be the effect. For if we seek to increase the ampl. of its vibrat. it almost necessarily follows that we distort the form of the vibration & thus obtain loudness at the expense of distinctness.

Our most distinct effects have been obtained when the pitch of the voice was high (with loud speech) — and the lower tones were distinct only when the articulation was soft. In both cases the amplitude was small.

Why not try the effect of the simultaneous vibration of a number of armatures in front of a number of electro-magnets included in the same circuit somewhat as in Fig 5

Fig 5.



~~Dear~~ I shall attempt to calculate the effect of arranging the magnets as in Figs 6 & 7.

Fig 6

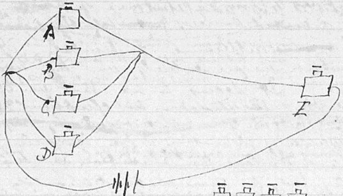


Fig 7

Ignore resistance of line & battery — & consider the current as divides equally between all the magnets. The problem is to obtain by the simultaneous vibration of the armatures of A B C & D — electrical undulations in E of as great amplitude as possible.

Electro-motive force ~~[illegible] = 100~~ = E
Resistance of circuit = R   Resistance of each magnet = 2
~~S~~ Strength of current = $S = \frac{E}{R}$

In Fig 7 $S = \frac{E}{5 \cdot 2}$; in Fig 6 $S' = \frac{E}{2 + \frac{2}{4}}$

~~Hence [illegible]~~ Hence $\frac{S}{S'} = \frac{1}{4}$

~~Ex~~ 8

Hence the strength of current in arrangement Fig 6 is four times that shown in Fig 7. But the current in Fig 6 divides into four branches A B C D hence the intensity of the current in each branch is one fourth of ~~the current~~ that passing through E.

Call the intensity of current in Fig 7 — 100 then in Fig 6 it is 400

In Fig 7
Intensity of current traversing
A = 100
B = 100
C = 100
D = 100
E = 100

In Fig 6
A = 100
B = 100
C = 100
D = 100
E = 400

In Fig 6 the four magnets A B C & D offer together one quarter the resist. of E and each magnet A, B, C, or D may be considered as constituting one fourth of that resist. (to [illegible] only one fourth the current passes through each) Hence each magnet A B C or D constitutes $\frac{1}{16}$th resist of E or $\frac{1}{20}$th resist of the whole circuit.
In Fig 7 each magnet constitutes $\frac{1}{5}$th the whole resist. of circ.

When the armature any of the mag. is made to vibrate in front of the pole — the current passing thr. the electro-mag. is alternately strength. & weakened. For simplicity let us suppose the resistance of the magnet to vary as there is a constant source of ~~pow~~ electrical power in the battery. Suppose max. resist. of mag. to be 12 and the minimum 8. and let only one of the magnets A B C or D have ~~the~~ vibrat. in its armat.

Then in Fig 6. Normal resist of magnets ~~A~~ = 10

Maxim. resist. of A = 12 Hence max. resist of circuit = 202
Minimum resist of A = 8 Hence min. resist. of circuit = 198

Now if all four armatures A B C D are caused to vibrate.

Max. resist of ABCD = 48 Hence max. resist. of circ = 208
min. resist. of ABCD = 32 Hence max. resist. of circ = 192

Normal resist of circuit = 200

In Fig 7. When one armature A is vibrated

Max. resist. of A = 12 Hence max. resist of circ. = 52
min. resist. of A = 8 Hence min. resist of circ. = 48

Normal resistance of circ. = 50

Now if all four arm. A B C D are caused to vibrate

Max. resist. of A B C D = 48 Hence max. resist of circ = 58
min resist of A B C D = 32 Hence min. res. of circ. = 42

In order to compare these results together we must express them comparatively. Now the normal resistance of circuit in Fig 7 is four times as great as circuit in Fig 6.

Let us call Normal resist. of Fig 6 = 100 and N. resist of Fig 7 = 400

Then in Fig 6 { Max. resist of circ. = 104 ; min. resist of circ = 96 }

~~min intensity = $\frac{1}{104}$~~
~~max. int. = $\frac{1}{96}$~~
~~min. int. = $\frac{1}{464}$~~
~~max. int. = $\frac{1}{336}$~~

In Fig 7 { Max resist of circ. = 464 ; min resist of circ. = 336 }

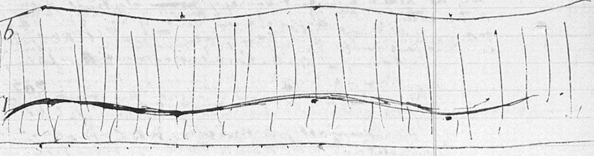
Then in Fig 6 min strength of current = $\frac{1}{104}$ = 0.9615 (0.009615)
max. st. of current = $\frac{1}{96}$ = 1.0416 (0.010416)

In Fig 7 min. st. of current = $\frac{1}{464}$ = 0.2155 (0.002155)
max. st. of current = $\frac{1}{336}$ = 0.2976 (0.002976)

Graphical representation of Electrical Undulations.

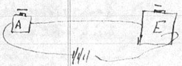
Fig 6

Fig 7



Compare with these the arrangement in Fig 8 where one electro-magnet A is used having a resistance equivalent to ABC+D in Fig 6; and that in Fig 9 where the electro-magnet A has a resistance equiv. to ABC+D Fig 7.

Fig 8



(In Fig 8)

Max. res. of A = 12 max. resist. of circ. = 52

Min. res. of A = 8 min. resist. of circ = 48

(In Fig 9)

M. res. of A = 48 max. resist. of circ = 58

min. r. of A = 32 min resist of circ = 42

Fig 9

Take Normal resist. of circuits in Figs 8 & 9 as the same as in ~~Fig~~ ~~C~~ 7 = 100

~~Max~~ max. res of circ. Fig 8 = 104

min. r. of circ. " " = 96

In Fig 9

Max. r. of C. = 116

Min. r. of C = 84

Intensity of current

Fig 8

min. intens. = $\frac{1}{104}$ = ~~0.009615~~ ~~0.9616~~

Max. int. = $\frac{1}{96}$ = 0.010416

Fig 9.

min. int. = $\frac{1}{116}$ = ~~0.008620b~~ ~~0.002103~~

max. int. = $\frac{1}{84}$ = 0.0119047

		Fig b Strength of current
Fig 6	min	= .96
	max	= 104
Fig 7	min	= 22
	max	= 30
Fig 8	min	= 96
	max	= 104
Fig 9	min	= 86
	max	= 119

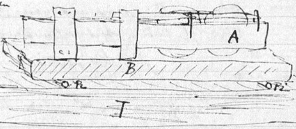
Notes of A. G. B. Sept. 28th /76.

Friday Sept 29th 1876

1. Repeated experiments ~~shown in Figs~~ described in Note 1 page 56 — Note 1 page 59 — Note 2 & 5 page 62 — Notes 1 & 2 page 79 — for the purpose of deciding which form of instrument works best. — We have so far found the results very variable — sometimes obtaining good vibrations — at other times failing.

Having noticed that the pressure of the finger upon the wooden base seemed to affect the vibration of the armature — we to-day determined to screw the base firmly to the table. We were unable to obtain more than a trace of vibration upon any of the above plans. While Mr. Watson was plucking the armature in the vain attempt to set it vibrating (on the plan shown in Fig I page 79) — I happened to be unscrewing one of the screws which fastened the base to the table + to our surprise the armature at once began to vibrate but with little amplitude. Upon screwing the base firmly again the vibration stopped nor could we cause its renewal until the base was loosened. It seems to be essential to the vibration that the base should be loose.

Fig I



2. We placed rubber pipes R R' between the base B and the table T (Fig I) The vibrations of A at once became intense.

~~Also~~ So long as the rubber tubes RR were retained in place all the experiments alluded to above were successful but the amplitude of A's vibration at once diminished when the base B came in contact with any solid object — + the vibration of A stopped when the base B was pressed firmly against the table.

3. The end A' (Fig 2) was observed to be in vibration. ~~also~~ When A' was held in the fingers or weighted — the amplitude of A's vibration was very greatly increased.

Fig 2

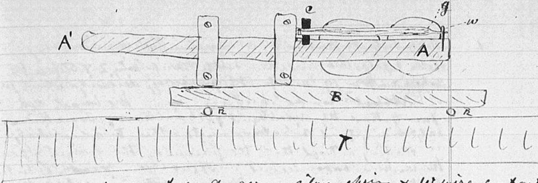


Fig 3 E

AA' armature. g german silver spring & W wire contact point
B Base R Rubber tubing T Table.

4. Upon looking downwards upon g (Fig 2) its vibration caused it to assume the appearance shown in Fig 3 — and a spark S showed where the contact was broken. Upon placing a card C between g & A (Fig 2) so as to increase the pressure between g and w — the amplitude of A's vibration was very much increased & the spark S shifted its place to S' showing that in the latter case the contact between (g & w)Fig 2 was not broken until the armature had completed its swing towards the electro-magnet E. When the spark was at S the circuit was broken when the armature ~~back~~ was half-way towards E and it was probably made again before it had completed its swing from E.

The position of the spark will evidently determine the duration of the make of the circuit, by showing the precise ~~place~~ spot where the circuit is broken.

5. Water spark arrester introduced annihilated the spark and diminished the amplitude of A's vibration when arranged as in Fig 2. ~~It however~~ The introduction of the spark-arrester however very perceptibly increased the vibration of A when arranged as in Fig 4.

(Fig 4)

6. Condenser reduced the spark & did not seem to affect vibration of A materially.

Notes Oct 1st 1876
by A. G. B.

Saturday Sept. 30th 1876

1. Intermittent current. Nothing new to-day. Have contented ourselves with verifying yesterday's experiments. Results obtained very important.

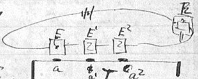
Rubber Tubes under base produce wonderful effect. Do not thoroughly understand cause. Perhaps magnet can only do a certain amount of work – and when rubber is omitted its force is partially expended in setting table in vibration, but with rubber it is all expended upon the armature producing greater amplitude of vibration. This explanation suggested by Mr. Watson.

Position of the spark affords a valuable index ~~to the~~ of the condition of the current. Do not understand the action of the ~~ttt~~ water spark-arrester in increasing amplit. of vib. in one case & diminishing it in the other.

Fig I

2. Undulatory.
Lever a f b – set in vibration by membrane m (sug. by W.W.).
Very slight audible effects from Receiver.
W.W. suggests magnet on each side of a to prevent the attract. of E from causing the end b of the lever to press upon m & thus interfere with its vibration.

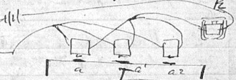
Fig 2



3. T Tambourine. a a' a2 armatures of Electro-magnets E E' E2.
Fixed to Tambourine.

Loudness at R noted in arrangement shown at Fig 4. Sounds audible but rather softly.

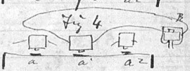
Fig 3



4. (Fig 3) Sounds barely audible much softer than in Fig 4.

5. (Fig 2) Sounds audible much more plainly than in either Figs 3 or 4 – but at best very faint.

Fig 4



Noted by A.G.B.
Oct. 1st 1876